CLAIMS

We claim:

1. A method for forming a thermal barrier coating system, the method comprising:

presenting at least one substrate;

depositing a bond coat on at least a portion of at least one said substrate; and

depositing at least one of zirconia, carbide, boride, refractory metal, zirconia alloy, carbide alloy, boride alloy, and/or refractory metal alloy or any combination thereof to form a deposition of a thermal-insulating layer on said bond coat.

2. The method of claim 1, wherein:

said refractory metal comprise at least one of Molydenum (Mo), Niobium (Nb), Tantalum (Ta), Titanium (Ti), or Tungsten (W), or any combination thereof; and

said refractory metal alloy comprise at least one of alloys of Mo, Nb, Ta, Ti or W, or any combination thereof.

3. The method of claim 1, wherein said carbide material comprise at least one of TiC, HfC, ZrC, TaC, W2C, SiC, alloys of TiC, HfC, ZrC, TiAl, TaC, W2C, SiC, or any combination thereof.

4. The method of claim 1, wherein said deposition of said bond coat and thermal insulating layer is accomplished with a deposition method comprising:

at least one of directed vapor deposition (DVD), chemical vapor deposition (CVD), evaporation (thermal, RF, laser, or electron beam), reactive evaporation, sputtering (DC, RF, microwave and/or magnetron), arc plasma deposition, reactive sputtering, electron beam physical vapor deposition (EF-PVD), electroplating, ion plasma deposition (IPD), low pressure plasma spray (LPPS), plasma spray (e.g., air plasma spray (APS)), high velocity oxy-fuel (HVOF), vapor deposition, or cluster deposition.

5. The method of claim 1, wherein said deposition of said bond coat and

thermal insulating layer is accomplished with a Directed Vapor Deposition (DVD).

6. The method of claim 5, wherein said DVD technique comprises:

said presenting of at least one of said substrate includes presenting said substrate to a chamber, wherein said chamber has an operating pressure ranging from about 0.1 to about 32,350 Pa,;

presenting at least one additional evaporant sources to said chamber if desired;

presenting at least one carrier gas stream to said chamber;

impinging said zirconia and/or at least one refractory metal or combination thereof or any of their alloys and/or said desired evaporant source with at least one energetic beam in said chamber to generate an evaporated vapor flux impinged by said electron beam; and

deflecting at least one of said generated evaporated vapor flux by at least one of said carrier gas stream, wherein said evaporated vapor flux:

at least partially coats at least one said substrate to form said bond coat, and

at least partially coats said bond coat to form said thermal-insulating layer coat.

7. The method of claim 6, wherein said energetic beam comprises at least one of electron beam source, laser source, heat source, ion bombardment source, highly focused incoherent light source, microwave, radio frequency, EMF, or any energetic beam that break chemical bonds, or any combination thereof.

8. The method of claim 6, further comprising:

said chamber further includes a substrate bias system capable of applying a DC or alternating potential to at least one of said substrates;

impinging said at least one of said generated vapor flux and at least one of said carrier gas stream with a working gas generated by at least one hollow cathode arc plasma activation source to ionize said at least one of said generated vapor flux and at least one of said carrier gas stream; and

attracting said ionized generated vapor flux and said carrier gas stream to a substrate surface by allowing a self-bias of said ionized gas and vapor stream or said potential to pull the ionized stream to said substrate.

9. The method of claim 8, said generated electrons from said hollow cathode source is regulated for direction through variations in the quantity of working gas passing through said hollow cathode source.

10. The process of claim 8, wherein the distance between said cathode source and said generated evaporated vapor flux is regulated for ionization of the entire generated evaporated vapor flux.

11. The method of claim 6, further comprising at least one nozzle, wherein said at least one carrier gas stream is generated from said at least one nozzle and said at least one evaporant source is disposed in said at least one nozzle

12. The method claim 11, wherein said evaporant retainer is a crucible.

13. The method of claim 6, further comprising:

said chamber further includes a substrate bias system capable of applying a DC or alternating potential to at least one of said substrates;

impinging said at least one of said generated vapor flux and at least one of said carrier gas stream with a low energy beam to ionize said at least one of said generated vapor flux and at least one of said carrier gas stream; and

attracting said ionized generated vapor flux and said carrier gas stream to a substrate surface by allowing a self-bias of said ionized gas and vapor stream or said potential to pull the ionized stream to said substrate.

14. The method of claim 6, wherein at least one of said at least one desired additional evaporant source is a material selected from the group consisting: NiY, NiAl,

PtAl, PtY, Ni, Y, Al, Pt, NiAlPt, NiYPt, NiPt, Co, Mo, Fe, Zr, Hf, Yb, and other reactive elements.

15. The method of claim 6, wherein at least one of said at least one desired additional evaporant sources is made from alloys formed of one or more of a material selected from the group consisting: NiY, NiAl, PtAl, Pty, Ni, Y, Al, Pt, NiAlPt, NiYPt, NiPt, Co, Mo, Fe, Zr, Hf, Yb, and other reactive elements.

16. A method for forming a thermal barrier coating system, the method comprising:

presenting at least one substrate;

depositing a bond coat on at least a portion of at least one said substrate;

depositing at least one of zirconia, carbide, boride, refractory metal, zirconia alloy, carbide alloy, boride alloy, and/or refractory metal alloy or any combination thereof to form a deposition of a thermal-insulating layer on said bond coat comprised of columnar grains; and

forming at least one recess in said substrate or said bond coat or at least one recess in each of said substrate and said bond coat, wherein said recess provide gaps between the columnar grains.

17. The method of claim 16, wherein said deposition of said bond coat and thermal insulating layer is accomplished with a deposition method comprising:

at least one of directed vapor deposition (DVD), chemical vapor deposition (CVD), evaporation (thermal, RF, laser, or electron beam), reactive evaporation, sputtering (DC, RF, microwave and/or magnetron), arc plasma deposition, reactive sputtering, electron beam physical vapor deposition (EF-PVD), electroplating, ion plasma deposition (IPD), low pressure plasma spray (LPPS), plasma spray (e.g., air plasma spray (APS)), high velocity oxy-fuel (HVOF), vapor deposition, or cluster deposition.

18. The method of claim 16, wherein said deposition of said bond coat and

thermal insulating layer is accomplished with a directed vapor deposition (DVD).

19. A method for forming a thermal barrier coating system, the method comprising:

presenting at least one substrate;

placing a screen in a predetermined distance above said substrate;

depositing a bond coat on at least a portion of at least one said substrate;

depositing at least one of zirconia, carbide, boride, refractory metal, zirconia alloy, carbide alloy, boride alloy, and/or refractory metal alloy, or any combination thereof to form a deposition of a thermal-insulating layer on said bond coat, whereby said screen causes a shadow effect on the deposition.

20. The method of claim 19, wherein said deposition of said bond coat and thermal insulating layer is accomplished with a deposition method comprising:

at least one of directed vapor deposition (DVD), chemical vapor deposition (CVD), evaporation (thermal, RF, laser, or electron beam), reactive evaporation, sputtering (DC, RF, microwave and/or magnetron), arc plasma deposition, reactive sputtering, electron beam physical vapor deposition (EF-PVD), electroplating, ion plasma deposition (IPD), low pressure plasma spray (LPPS), plasma spray (e.g., air plasma spray (APS)), high velocity oxy-fuel (HVOF), vapor deposition, or cluster deposition.

21. The method of claim 19, wherein said deposition of said bond coat and thermal insulating layer is accomplished with a Directed Vapor Deposition (DVD).

22. A method for forming a thermal barrier coating system, the method comprising:

presenting at least one substrate;

depositing a bond coat on at least a portion of at least one said substrate;

depositing at least a first evaporant source, said first evaporant source comprising:

zirconia, carbide, boride, refractory metal, zirconia alloy, carbide alloy,

boride alloy, and/or refractory alloy or any combination thereof;

depositing at least a second evaporant source, said second evaporant source comprising:

at least one material insoluble with said first evaporant source;

said first and second evaporations forming a deposition of a thermal-insulating layer comprised of having columnar grains, wherein said first evaporations produce secondary grains to provide gaps between the columnar grains.

23. The method of claim 22, wherein said insoluble material comprise at least one of metal, alloys, or salt, or any combination thereof.

24. The method of claim 22, wherein said deposition of said bond coat and thermal insulating layer is accomplished with a deposition method comprising:

at least one of directed vapor deposition (DVD), chemical vapor deposition (CVD), evaporation (thermal, RF, laser, or electron beam), reactive evaporation, sputtering (DC, RF, microwave and/or magnetron), arc plasma deposition, reactive sputtering, electron beam physical vapor deposition (EF-PVD), electroplating, ion plasma deposition (IPD), low pressure plasma spray (LPPS), plasma spray (e.g., air plasma spray (APS)), high velocity oxy-fuel (HVOF), vapor deposition, or cluster deposition.

25. The method of claim 22, wherein said deposition of said bond coat and thermal insulating layer is accomplished with a Directed Vapor Deposition (DVD).

26. A method for forming a thermal barrier coating system, the method comprising:

presenting at least one substrate;

depositing a bond coat on at least a portion of at least one said;

providing a sacrificial template in a predetermined distance above said substrate or said bond coat;

depositing at least one of zirconia, carbide, boride, refractory metal, zirconia alloy,

carbide alloy, boride alloy, and/or refractory metal alloy or any combination thereof to form a deposition of a thermal-insulating layer on said sacrificial template;

evaporating said sacrificial template leaving a hollow shell.

27. The method of claim 26, wherein said sacrificial template comprises at least one of solid ligament foam structure, hollow ligament foam structure, mesh structure, stacked mesh structure, screen structure, stacked screen structure, interwoven wires structure , serpentine rows, random pattern structure, 3-D array structure, truss structure, tubes structure, periodic cells structure, stochastic cells structure, 3-D cellular structure, 3-D cellular truss or any combination thereof.

28. The method of claim 26, wherein said deposition of said bond coat and thermal insulating layer is accomplished with a deposition method comprising:

at least one of directed vapor deposition (DVD), chemical vapor deposition (CVD), evaporation (thermal, RF, laser, or electron beam), reactive evaporation, sputtering (DC, RF, microwave and/or magnetron), arc plasma deposition, reactive sputtering, electron beam physical vapor deposition (EF-PVD), electroplating, ion plasma deposition (IPD), low pressure plasma spray (LPPS), plasma spray (e.g., air plasma spray (APS)), high velocity oxy-fuel (HVOF), vapor deposition, or cluster deposition.

29. The method of claim 26, wherein said deposition of said bond coat and thermal insulating layer is accomplished with a Directed Vapor Deposition (DVD).

30. A deposition apparatus for forming a thermal barrier coating system, the apparatus comprising:

a housing, wherein at least one substrate is presented in said housing;

a deposition means for depositing a bond coat on at least a portion of at least one said substrate; and

said deposition means for depositing at least one of zirconia, carbide, boride, refractory metal, zirconia alloy, carbide alloy, boride alloy, and/or refractory metal alloy

or any combination thereof to form a deposition of a thermal-insulating layer on said bond coat.

31. The apparatus of claim 30, wherein said deposition means comprises:

at least one of directed vapor deposition (DVD) apparatus, chemical vapor deposition (CVD) apparatus, evaporation (thermal, RF, laser, or electron beam) apparatus, reactive evaporation apparatus, sputtering (DC, RF, microwave and/or magnetron) apparatus, arc plasma deposition apparatus, reactive sputtering apparatus, electron beam physical vapor deposition (EF-PVD) apparatus, electroplating apparatus, ion plasma deposition (IPD) apparatus, low pressure plasma spray (LPPS) apparatus, plasma spray (e.g., air plasma spray (APS)) apparatus, high velocity oxy-fuel (HVOF) apparatus, vapor deposition apparatus, or cluster deposition apparatus.

32. The apparatus of claim 30, wherein said deposition means comprises:

a directed vapor deposition (DVD) apparatus.

33. The method of claim 30, wherein:

said refractory metal comprise at least one of Molydenum (Mo), Niobium (Nb), Tantalum (Ta), Titanium (Ti), or Tungsten (W), or any combination thereof; and

said refractory metal alloy comprise at least one of alloys of Mo, Nb, Ta, Ti or W, or any combination thereof.

34. The method of claim 30, wherein said carbide material comprise at least one of TiC, HfC, ZrC, TaC, W2C, SiC, alloys of TiC, HfC, ZrC, TiAl, TaC, W2C, SiC, or any combination thereof.

35. A directed vapor deposition (DVD) apparatus for forming a thermal barrier coating system, the apparatus comprising:

a chamber, wherein said chamber has an operating pressure ranging from about 0.1 to about 32,350 Pa, wherein at least one substrate is presented in said chamber;

at least one evaporant source disposed in said chamber;

at least one carrier gas stream provided in said chamber; and

an energetic beam system providing at least one energetic beam,

said energetic beam:

impinging at least one said evaporant source with at least one said energetic beam in said chamber to generate a bond coat evaporated vapor flux, and

deflecting at least one of said generated bond coat evaporated vapor flux by at least one of said carrier gas stream, wherein said bond coat evaporated vapor flux at least partially coats at least one of said substrates to form said bond coat; and

said energetic beam:

impinging at least one of said evaporant source with at least one said energetic beam in said chamber to generate a thermal-insulating layer evaporated vapor flux, wherein said evaporant source for generating said thermal-insulating layer comprise at least one of zirconia, carbides, borides, and/or at least one refractory metal or combination thereof or any of their alloys, and

deflecting at least one of said thermal-insulating layer generated evaporated vapor flux by at least one of said carrier gas stream, wherein said thermal-insulating layer evaporated vapor flux at least partially coats at least one of said substrates to form said thermal-insulating layer on said bond coat.

36. The method of claim 35, wherein said energetic beam comprises at least one of electron beam source, electron gun source, laser source, heat source, ion bombardment source, highly focused incoherent light source, microwave, radio frequency, EMF, or any energetic beam system that breaks chemical bonds, or combination thereof.

37. The apparatus of claim 35, further comprising:

a substrate bias system capable of applying a DC or alternating potential to at least one of said substrates;

at least one hollow cathode arc source generating a low voltage beam, said at least one hollow cathode arc source:

impinging said at least one of said generated vapor flux and at least one of said carrier gas stream with a working gas generated by at least one said hollow cathode arc plasma activation source to ionize said at least one of said generated vapor flux and at least one of said carrier gas stream; and

attracting said ionized generated vapor flux and said carrier gas stream to a substrate surface by allowing a self-bias of said ionized gas and vapor stream or said potential to pull the ionized stream to said substrate.

38. The apparatus of claim 37, wherein said hollow cathode arc source comprises at least one cathode orifice wherein a predetermined selection of said cathode orifices are arranged in close proximity to the gas and vapor stream; and

an anode is arranged opposite of said cathode source wherein the gas and vapor stream is there between said cathode source and said anode.

39. The apparatus of claim 35, further comprising at least one nozzle, wherein said at least one carrier gas stream is generated from said at least one nozzle and said at least one evaporant source is disposed in said at least one nozzle, wherein said at least one said nozzle comprises:

at least one nozzle gap wherein said at least one said carrier gas flows there from; and

at least one evaporant retainer for retaining at least one said evaporant source, said evaporant retainer being at least substantially surrounded by at least one said nozzle gap.

40. The apparatus of claim 39, wherein said evaporant retainer is a crucible.

41. The apparatus of claim 35, further comprising:

a substrate bias system capable of applying a DC or alternating potential to at least one of said substrates;

at least one low energy beam source for generating a low voltage beam, said at least one low energy beam source:

impinging said at least one of said generated vapor flux and at least one of said carrier gas stream with a low energy beam to ionize said at least one of said generated vapor flux and at least one of said carrier gas stream; and

attracting said ionized generated vapor flux and said carrier gas stream to a substrate surface by allowing a self-bias of said ionized gas and vapor stream or said potential to pull the ionized stream to said substrate.

42. A deposition apparatus for forming a thermal barrier coating system, the apparatus comprising:

a housing, wherein at least one substrate is presented in said housing;

a deposition means, said deposition means for depositing a bond coat on at least a portion of at least one said substrate;

said deposition means for depositing at least one of zirconia, carbide, boride, refractory metal, zirconia alloy, carbide alloy, boride alloy, and/or refractory metal alloy or any combination thereof to form a deposition of a thermal-insulating layer on said bond coat comprised of columnar grains; and

a recess provider means, said recess provider means for forming at least one recess in said substrate or said bond coat or at least one recess in each of said substrate and said bond coat, wherein said recess provide gaps between the columnar grains.

43. The apparatus of claim 42, wherein said deposition means comprises:

at least one of directed vapor deposition (DVD) apparatus, chemical vapor deposition (CVD) apparatus, evaporation (thermal, RF, laser, or electron beam) apparatus, reactive evaporation apparatus, sputtering (DC, RF, microwave and/or magnetron) apparatus, arc plasma deposition apparatus, reactive sputtering apparatus,

electron beam physical vapor deposition (EF-PVD) apparatus, electroplating apparatus, ion plasma deposition (IPD) apparatus, low pressure plasma spray (LPPS) apparatus, plasma spray (e.g., air plasma spray (APS)) apparatus, high velocity oxy-fuel (HVOF) apparatus, vapor deposition apparatus, or cluster deposition apparatus.

44. The apparatus of claim 42, wherein said deposition means comprises:

a directed vapor deposition (DVD) apparatus.

45. The apparatus of claim 42, wherein said recess provider means comprises at least one of:

etching device, masking device, tooling device, laser device, drilling device, energetic beam device, ablation device, hammering device, photoengraving device, lithographic device, and micromachining device.

46. A directed vapor deposition (DVD) apparatus for forming a thermal barrier coating system, the apparatus comprising:

a chamber, wherein said chamber has an operating pressure ranging from about 0.1 to about 32,350 Pa, wherein at least one substrate is presented in said chamber;

at least one evaporant source disposed in said chamber;

at least one carrier gas stream provided in said chamber; and

an energetic beam system providing at least one energetic beam,

said energetic beam:

impinging at least one said evaporant source with at least one said energetic beam in said chamber to generate a bond coat evaporated vapor flux, and

deflecting at least one of said generated bond coat evaporated vapor flux by at least one of said carrier gas stream, wherein said bond coat evaporated vapor flux at least partially coats at least one of said substrates to form said bond coat; and

said energetic beam:

impinging at least one of said evaporant source with at least one said energetic beam in said chamber to generate a thermal-insulating layer evaporated vapor flux, wherein said evaporant source for generating said thermal-insulating layer comprise at least one of zirconia, carbides, borides, and/or at least one refractory metal or combination thereof or any of their alloys, and

deflecting at least one of said thermal-insulating layer generated evaporated vapor flux by at least one of said carrier gas stream, wherein said thermal-insulating layer evaporated vapor flux at least partially coats at least one of said substrates to form said thermal-insulating layer on said bond coat comprising columnar grains; and

a recess provider means, said recess provider means for providing at least one recess in at least one of said bond coat or said thermal-insulating layer.

47. The apparatus of claim 46, wherein said recess provider means comprises at least one of :

etching device, masking device, tooling device, laser device, drilling device, energetic beam device, ablation device, hammering device, photoengraving device, lithographic device, and micromachining device.

48. A deposition apparatus for forming a thermal barrier coating system, the apparatus comprising:

a housing, wherein at least one substrate is presented in said housing;

a depositing means, said depositing means for depositing a bond coat on at least a portion of at least one said substrate;

said depositing means for depositing at least one of zirconia, carbide, boride, refractory metal, zirconia alloy, carbide alloy, boride alloy, and/or refractory alloy, or any combination thereof to form a deposition of a thermal-insulating layer; and

a screening means, said securing means causing a shadow effect on the deposition of said thermal-insulating layer.

49. The apparatus of claim 48, wherein said deposition means comprises:

at least one of directed vapor deposition (DVD) apparatus, chemical vapor deposition (CVD) apparatus, evaporation (thermal, RF, laser, or electron beam) apparatus, reactive evaporation apparatus, sputtering (DC, RF, microwave and/or magnetron) apparatus, arc plasma deposition apparatus, reactive sputtering apparatus, electron beam physical vapor deposition (EF-PVD) apparatus, electroplating apparatus, ion plasma deposition (IPD) apparatus, low pressure plasma spray (LPPS) apparatus, plasma spray (e.g., air plasma spray (APS)) apparatus, high velocity oxy-fuel (HVOF) apparatus, vapor deposition apparatus, or cluster deposition apparatus.

50. The apparatus of claim 48, wherein said deposition means comprises:

a directed vapor deposition (DVD) apparatus.

51. The apparatus of claim 48, wherein said screening means being located at at least one predetermined distance above said substrate.

52. The apparatus of claim 48, wherein:

said screening means being located at a at least one predetermined distance above said substrate; and

said screening means comprising at least one of screen, mesh, and/or mask, or any combination thereof.

53. A directed vapor deposition (DVD) apparatus for forming a thermal barrier coating system, the apparatus comprising:

a chamber, wherein said chamber has an operating pressure ranging from about 0.1 to about 32,350 Pa, wherein at least one substrate is presented in said chamber;

at least one evaporant source disposed in said chamber;

at least one carrier gas stream provided in said chamber; and

an energetic beam system providing at least one energetic beam,

said energetic beam:

impinging at least one said evaporant source with at least one said energetic beam in said chamber to generate a bond coat evaporated vapor flux, and

deflecting at least one of said generated bond coat evaporated vapor flux by at least one of said carrier gas stream, wherein said bond coat evaporated vapor flux at least partially coats at least one of said substrates to form said bond coat; and

said energetic beam:

impinging at least one of said evaporant source with at least one said energetic beam in said chamber to generate a thermal-insulating layer evaporated vapor flux, wherein said evaporant source for generating said thermal-insulating layer comprise at least one of zirconia, carbides, borides and/or at least one refractory metal or combination thereof or any of their alloys, and

deflecting at least one of said thermal-insulating layer generated evaporated vapor flux by at least one of said carrier gas stream, wherein said thermal-insulating layer evaporated vapor flux at least partially coats at least one of said substrates to form said thermal-insulating layer on said bond coat comprising columnar grains; and

a screen provider means, said screen provider means for providing a screen while at least one of said bond coat or said thermal insulating layer is being formed.

54. A deposition apparatus for forming a thermal barrier coating system, the apparatus comprising:

a housing, wherein at least one substrate is presented in said housing;

a depositing means, said depositing means for depositing a bond coat on at least a portion of at least one said substrate;

said depositing means for depositing at least a first evaporant source, said first evaporant source comprising:

zirconia, carbide, boride, refractory metal, zirconia alloy, carbide alloy,

boride alloy, and/or refractory alloy or any combination thereof;

said depositing means for depositing at least a second evaporant source, said second evaporant source comprising:

at least one material insoluble with said first evaporant source;

said first and second evaporations forming a deposition of a thermal-insulating layer comprised of having columnar grains, wherein said first evaporations produce secondary grains to provide gaps between the columnar grains.

55. The apparatus of claim 54, wherein said deposition means comprises:

at least one of directed vapor deposition (DVD) apparatus, chemical vapor deposition (CVD) apparatus, evaporation (thermal, RF, laser, or electron beam) apparatus, reactive evaporation apparatus, sputtering (DC, RF, microwave and/or magnetron) apparatus, arc plasma deposition apparatus, reactive sputtering apparatus, electron beam physical vapor deposition (EF-PVD) apparatus, electroplating apparatus, ion plasma deposition (IPD) apparatus, low pressure plasma spray (LPPS) apparatus, plasma spray (e.g., air plasma spray (APS)) apparatus, high velocity oxy-fuel (HVOF) apparatus, vapor deposition apparatus, or cluster deposition apparatus.

56. The apparatus of claim 54, wherein said deposition means comprises:

a directed vapor deposition (DVD) apparatus.

57. A directed vapor deposition (DVD) apparatus for forming a thermal barrier coating system, the apparatus comprising:

a chamber, wherein said chamber has an operating pressure ranging from about 0.1 to about 32,350 Pa, wherein at least one substrate is presented in said chamber;

at least one evaporant source disposed in said chamber;

at least one carrier gas stream provided in said chamber; and

an energetic beam system providing at least one energetic beam,

said energetic beam:

impinging at least one said evaporant source with at least one said energetic beam in said chamber to generate a bond coat evaporated vapor flux, and

deflecting at least one of said generated bond coat evaporated vapor flux by at least one of said carrier gas stream, wherein said bond coat evaporated vapor flux at least partially coats at least one of said substrates to form said bond coat; and

said energetic beam:

impinging at least one of said evaporant source with at least one said energetic beam in said chamber to generate a thermal-insulating layer evaporated vapor flux, wherein said evaporant source for generating said thermal-insulating layer comprise at least one of zirconia, carbides, borides, and/or at least one refractory metal or combination thereof or any of their alloys, and

deflecting at least one of said thermal-insulating layer generated evaporated vapor flux by at least one of said carrier gas stream, wherein said thermal-insulating layer evaporated vapor flux at least partially coats at least one of said substrates to form said thermal-insulating layer on said bond coat comprising columnar grains; and

said energetic beam:

impinging at least one of insoluble source with at least one said energetic beam in said chamber to generate secondary grains in said thermal-insulating layer to provide gaps or structured porosity in said columnar grains.

58. A coating system on a substrate, the coating system comprising:

a bond coat in communication with at least a portion of said substrate, said bond coat produced by deposition technique; and

a thermal-insulating layer in communication with at least a portion of said bond coat, said thermal-insulating layer comprising at least one of zirconia, carbide, boride,

refractory metal, zirconia alloy, carbide alloy, boride alloy, and/or refractory metal alloy, or any combination thereof.

59. The system of claim 58, wherein:

said refractory metal comprise at least one of Molydenum (Mo), Niobium (Nb), Tantalum (Ta), Titanium (Ti), or Tungsten (W), or any combination thereof; and

said refractory metal alloy comprise at least one of alloys of Mo, Nb, Ta, Ti or W, or any combination thereof.

60. The method of claim 58, wherein said carbide material comprise at least one of TiC, HfC, ZrC, TaC, W2C, SiC, alloys of TiC, HfC, ZrC, TiAl, TaC, W2C, SiC, or any combination thereof.

61. The system of claim 58, further comprising:

at least one recess in at least one of said substrate or said bond coat.

62. The system of claim 61, wherein said recess comprises a columnar gap inducing geometry.

63. The system of claim 61, wherein said recess comprises:

at least one of indentation, aperture, port, duct, groove, channel, dimple, bore, inlet, outlet, hole, conduit, perforation, channel, passage, pipe, tube, slot, flute, well, and/or tunnel, or any combination thereof.

64. The system of claim 58, wherein said thermal-insulating layer comprise plurality of columnar grains having an outer surface comprising gaps there between, wherein:

said gaps at the outer surface amounts to about ten percent or greater of the distance spanning across opposite-outside limits of two adjacent columns.

65. The system of claim 58, wherein said thermal-insulating layer comprise plurality of columnar grains having an outer surface comprising gaps there between, wherein:

said gaps at the outer surface amounts to about five percent or greater of the distance spanning across opposite-outside limits of two adjacent columns.

66. The system of claim 58, wherein said thermal-insulating layer is a three-dimensional truss structure.

67. The system of claim 58, wherein said thermal-insulating layer is a three-dimensional cellular structure.

68. The system of claim 58, wherein said thermal-insulating layer is a reticulated foam structure.

69. The system of claim 58, wherein said substrate is at least one of:

rocket engine component, space reentry vehicle component, scram jet component, hypersonic vehicle component, fusion reactor component, gas turbine engine component, diesel engine component, turbine blade, and airfoil.

70. The system of claim 58, wherein said deposition technique of said bond coat and thermal insulating layer is accomplished with a deposition method comprising:

at least one of directed vapor deposition (DVD), chemical vapor deposition (CVD), evaporation (thermal, RF, laser, or electron beam), reactive evaporation, sputtering (DC, RF, microwave and/or magnetron), arc plasma deposition, reactive sputtering, electron beam physical vapor deposition (EF-PVD), electroplating, ion plasma deposition (IPD), low pressure plasma spray (LPPS), plasma spray (e.g., air plasma spray (APS)), high velocity oxy-fuel (HVOF), vapor deposition, or cluster deposition.

71. The system of claim 58, wherein said deposition technique of said bond

coat and thermal insulating layer is accomplished with a directed vapor deposition (DVD).